6-12: Hurricanes as Heat Engines Lesson Plan

Purpose**:** Using the various visualizations (i.e., images, charts, and graphs) from 2016 Hurricane Matthew, students explore the energy exchange that occurs when hurricanes extract heat energy from the ocean.

<table>
<tr>
<td>Grade Level: 6-12
Time: 1- 90 minute class periods or 2- 45 minute class periods
MND Lesson # 50 (Revised)</td>
<td>Lesson Objectives:
Students will analyze NASA sea surface temperature data to use as evidence to explain a phenomenon.
Students will explore how hurricanes gain energy from the ocean surface.</td>
<td>Sphere(s):
Atmosphere
Hydrosphere</td>
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<tr>
<td colspan="3">Phenomena NASA Connection:
Hurricanes are the most violent storms on Earth. They are like giant engines that use warm, moist air as fuel, which is why they form only over warm ocean waters near the equator. The warm, moist air over the ocean rises upward and as the air continues to rise the surrounding air swirls in to take its place. As the warm, moist air rises and cools off clouds form creating a system of clouds and wind that spins and grows, fed by the ocean's heat and water evaporating from the surface. NASA satellites gather sea surface temperature data that can be used to explore changes that occur.</td>
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<tr>
<td colspan="3">Essential Questions:
How is sea surface temperature affected by the development of a hurricane?
How is thermal energy transferred within a hurricane system?
How does a hurricane affect the different spheres within the Earth system?</td>
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<tr>
<td colspan="3">Grades 6-8 NGSS Performance Expectations:
MS-PS1-4 Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
MS-PS3-5 Construct, use and present arguments to support the claim that when kinetic energy of an object changes, energy is transferred to or from the object.</td>
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<td>Science & Engineering Practices:

Developing and Using Models: Develop a model to predict and/or describe phenomena.

Engaging in Argument from Evidence: Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon.</td>
<td>Disciplinary Core Ideas:
PS1.A: Structure and Properties of Matter
Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.
PS3.A: Definitions of Energy
The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to</td>
<td>Crosscutting Concepts:

Cause and Effect
Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Energy and Matter

Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).</td>
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	another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material.	

NCTM Math Standards: n/a

Cross-Curricular Connections: **National Geography Standards**

-How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.

STEM Career Connections:

- **Atmospheric and Space Scientists** – Investigate weather and climate related phenomena to prepare weather and climate related phenomena to prepare weather reports and forecasts for the public
- **Computer and Information Scientists** – Conduct research in the field of computer and information science
- **Applications Software Developers** – Develop and modify computer applications software that are used to communicate with satellites and people using satellite data

-Computer Programmers

-Systems Engineers

-Software Engineers

Multimedia Resources: *(Can be displayed or distributed to student groups as hard copies)*

- Path of Hurricane Matthew September 28 – October 9, 2016
- Progression of Matthew, https://coast.noaa.gov/hurricanes/
- Saffir-Simpson Hurricane Wind Scale, http://www.nhc.noaa.gov/aboutsshws.php
- My NASA Data, https://mynasadata.larc.nasa.gov/
- CYGNSS Mission, https://www.nasa.gov/cygnss

Materials/Resources Needed:

Per Student:

- "Hurricanes as Heat Engines" Student Datasheet

Per Group:

- Numerous sticky notes in four different colors
- Markers
- Laptop
- Internet Access
- Data Visualization Pages: Daily Sea Surface Temperature for Oct. 4th, Oct. 8th, 12th
- Line Graph of Data: Sea Surface Temperature Graph for Oct. 1-16, 2016

Key Vocabulary:

- Coordinates
- Longitude
- Heat
- Sea Surface Temperature (SST)
- Latitude
- Upwelling
- Energy Transfer

Background Information:

The passage of a hurricane causes a large transfer of heat between the ocean surface and the atmosphere. It also causes surface waters to diverge, bringing cooler water from below to the surface (upwelling). These effects are so large that they can be seen by a drop in sea surface temperature (SST) in satellite data observations along the path of the storm. The cooler water conditions may last for a week or longer after the storm.

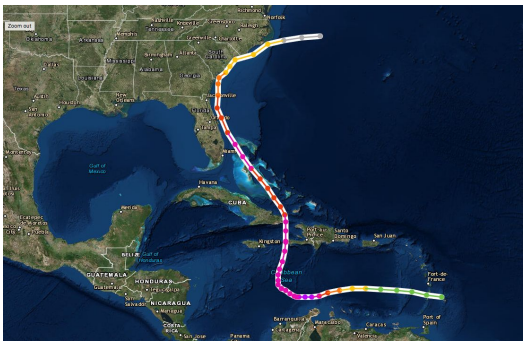
Prerequisite Student Knowledge:

- Introduction to weather or hurricanes
- Familiarity with finding coordinates on a map
- Basic concepts of energy transfer

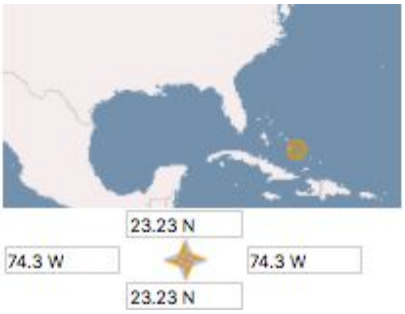
Procedure:

Setting the Stage:

1. Display "Path of Hurricane Matthew September 28 – October 9, 2016 Map" to students.
    a. Review the legend.
    b. Ask students to make observations about the path of Hurricane Matthew. What do the dots mean? What do their colors represent?
    c. Introduce and review the category legend.
    d. Draw students attention to the hurricanes' progression from a Tropical Storm to a Category 5.



2. Display the "Progression of Matthew" table to the students.
3. Draw a timeline to include each day on the board, starting with Sept. 28, 2016 and ending with Oct. 9th on the board taking up at least two meters or more. Label as Hurricane Matthew.
4. Break students into seven groups and distribute sticky notes using a different color for each category and markers.
    a. Divide the categories by each team: TS, H1, H2, H3, H4, H5, ET
    b. In teams, have students research their category identifying how many of these dates correspond with their category. They should research the effects of their category and write these effects on the correct color of sticky note. (**Note**, this step may need to be duplicated based on how many dates this category was experienced (e.g., Hurricane Matthew was a H1 on 9/29/2016, as well as on 10/8/2016 so these sticky notes will need to be made for each day.) Once completed, have students place their sticky notes on the date/s where these effects happened and present their findings.



Review the following questions with students:

1. How many days did it take Tropical Storm Matthew to become a category 5 hurricane?
2. How many days did it take Hurricane Matthew to no longer be classified as a hurricane?
3. Where does the energy come from that causes a tropical storm to become a category 5 hurricanes

Looking at the Data

a. Distribute the Daily Sea Surface Temperature for Oct. 4th with students.

b. Repeat with Oct. 8th and 12th.
c. Next show the location selected as a point of interest.
d. Display the Daily Sea Surface Temperature for Hurricane Matthew for Oct. 1-16, 2016
e. Distribute "Hurricanes as Heat Engines" Datasheet and review the instructions.

Examine the three data sets of Daily Sea Surface Temperature (SST) for October 4, 2016, October 8, 2016, and October 12, 2016 and describe your observations and inferences in the question below.

1. What evidence of lowered sea surface temperature (SST) do you observe in the map visualizations?

Examine the line graph of SST for the selected location and answer the questions below:

1. What effect do you observe regarding the temperature in the line plot ***after*** the hurricane passed?
2. How long did it take for the SST to return to the previous temperature?
3. What conclusion can you make about the the relationship of hurricanes and the ocean?
4. What other spheres besides the Atmosphere and Hydrosphere are affected?

Going Further

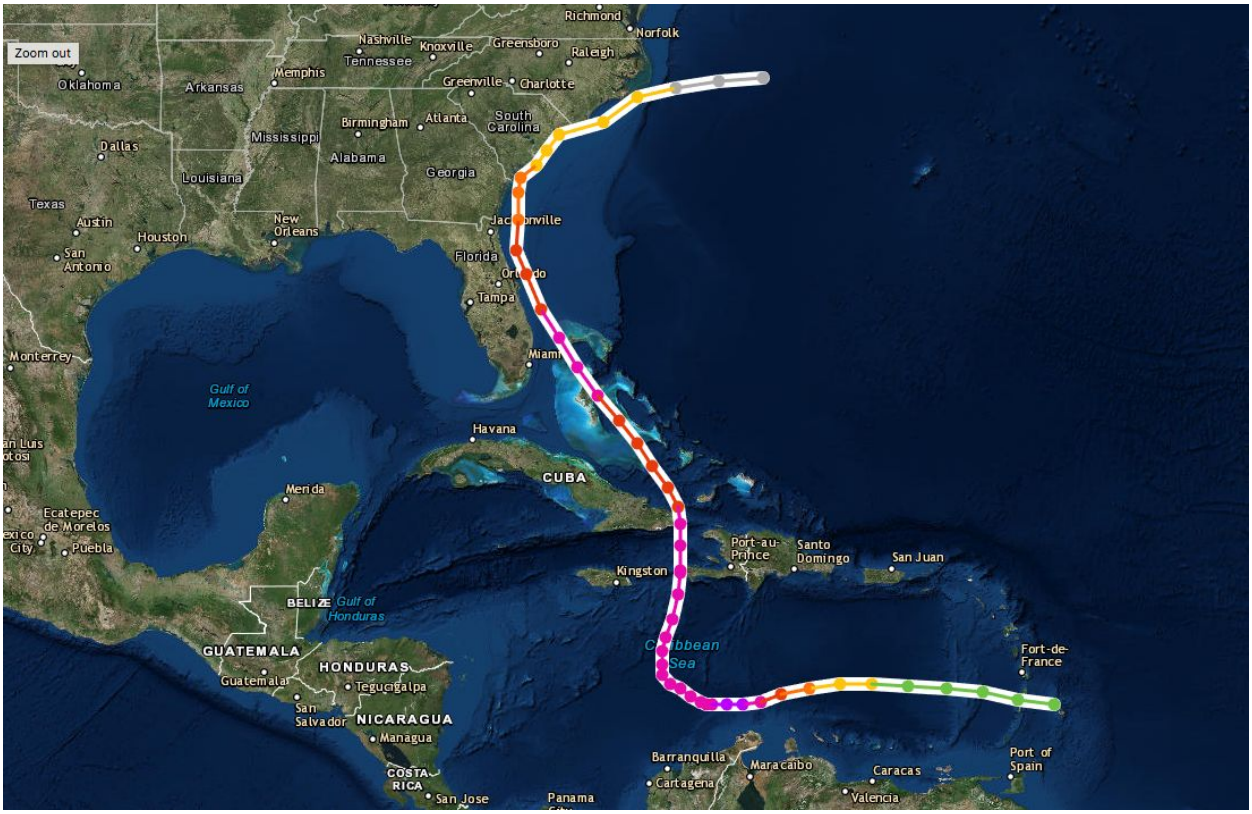
a. Using the same procedure, students will examine the SST data during and after Hurricane Harvey 2017 or any of the historical hurricanes from an area near where you live. (***Note:*** *Data is not available for the week after Hurricane Katrina because the hurricane interrupted data processing at the Naval Oceanographic Office at Stennis Space Center, Mississippi.)*
b. Review the instructions for Part B.

Going Further

1. Name of Hurricane:
2. Date of landfall:
3. How is SST affected by the hurricane that you selected?
4. What effect do you think these differences in the Hydrosphere might have on other spheres within the Earth system?
5. Pose three additional questions that you might have for further research. Identify other kinds of data would need to explore these questions?

New Research Question	New Datasets Needed to Explore this Question
1.	
2.	
3.	

Path of Hurricane Matthew September 28 – October 9, 2016



Category Legend:

Progression of Matthew

Date	Category
September 28, 2016	TS
September 29, 2016	H1
September 30, 2016	H2-H4
October 1, 2016	H5-H4
October 5, 2016	H3
October 6, 2016	H4
October 7, 2016	H3
October 8, 2016	H2-H1
October 9, 2016	ET

Saffir-Simpson Hurricane Wind Scale

Description of Damage Associated with Categories of Hurricanes

Category	Sustained Winds	Types of Damage Due to Hurricane Winds
1	74-95 mph 119-153 km/h	**Very dangerous winds will produce some damage**: Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.
2	96-110 mph 154-177 km/h	**Extremely dangerous winds will cause extensive damage**: Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3 (major)	111-129 mph 178-208 km/h	**Devastating damage will occur**: Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4 (major)	130-156 mph 209-251 km/h	**Catastrophic damage will occur**: Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5 (major)	157 mph or higher 252 km/h or higher	**Catastrophic damage will occur**: A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Student Datasheet

Name: _____
Date: _____

Hurricanes as Heat Engines

Part A: Looking at the Data
Examine the three data sets of Daily Sea Surface Temperature (SST) for October 4, 2016, October 8, 2016, and October 12, 2016 and describe your observations and inferences to the questions below in your science journal.

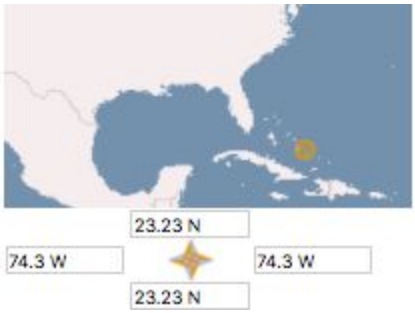
1. What evidence of lowered sea surface temperature (SST) do you observe in the map visualizations?

2. Examine the Line Graph: What effect do you observe regarding the temperature in the line plot ***after*** the hurricane passed?

3. How long did it take for the SST to return to the previous temperature?

4. What conclusion can you make about the the relationship of hurricanes and the ocean?

5. What other spheres besides the Atmosphere and Hydrosphere are affected?



Part B: Going Further Using the same procedure, examine the SST data during and after Hurricane Harvey 2017, Hurricane Irma or any of the historical hurricanes from an area near where you live.	**Data Sources:** My NASA Data: https://mynasadata.larc.nasa.gov/ CYGNSS Mission: https://www.nasa.gov/cygnss

1. Name of Hurricane:
2. Date of landfall:
3. How is SST affected by the hurricane that you selected?
4. What effect do you think these differences in the Hydrosphere might have on other spheres of the Earth system?

5. Pose three questions that you might have for further research, in the table below. Identify the types of data that would needed to explore these questions.

New Research Question	New Datasets Needed to Explore this Question
1.	
2.	
3.	

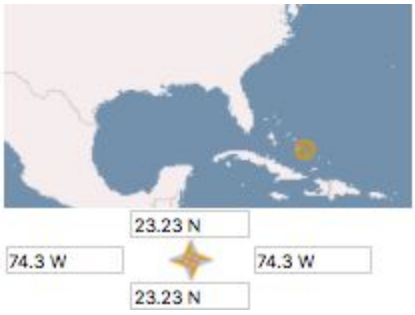
Name: _____ **TEACHER KEY**
Date: _____ **Student Datasheet**

Hurricanes as Heat Engines

Part A: Looking at the Data

Examine the three data sets of Daily Sea Surface Temperature (SST) for October 4, 2016, October 8, 2016, and October 12, 2016 and describe your observations and inferences to the questions below in your science journal.

1. What evidence of lowered sea surface temperature (SST) do you observe in the map visualizations?
   As time progresses from 10/4 – 10/12, the waters proximal to Texas become cooler, and the waters around Cuba and the Caribbean warm and become more homogeneous.
2. Examine the Line Graph: What effect do you observe regarding the temperature in the line plot ***after*** the hurricane passed?
   There is a cooling trend from Oct. 1-22, the about 1.5 °C which occurred more quickly than the rebounding temperature.
3. How long did it take for the SST to return to the previous temperature?
   The dataset does not provide the time it took to rebound to the starting temperature of 29.7 °C. The graph shows that the water warmed to over 29 °C in 3.5 days.
4. What conclusion can you make about the the relationship of hurricanes and the ocean? There is a cooling effect in SST as a hurricane passes over the location.



5. What other spheres besides the Atmosphere and Hydrosphere are affected?
   The biosphere as evidenced by the displacement of humans and other animals such as manatees, whales, turtles. Also plants such as sea grasses and the mangroves may be uprooted. Also, the geosphere may be affected by erosion of the beach and other landforms.

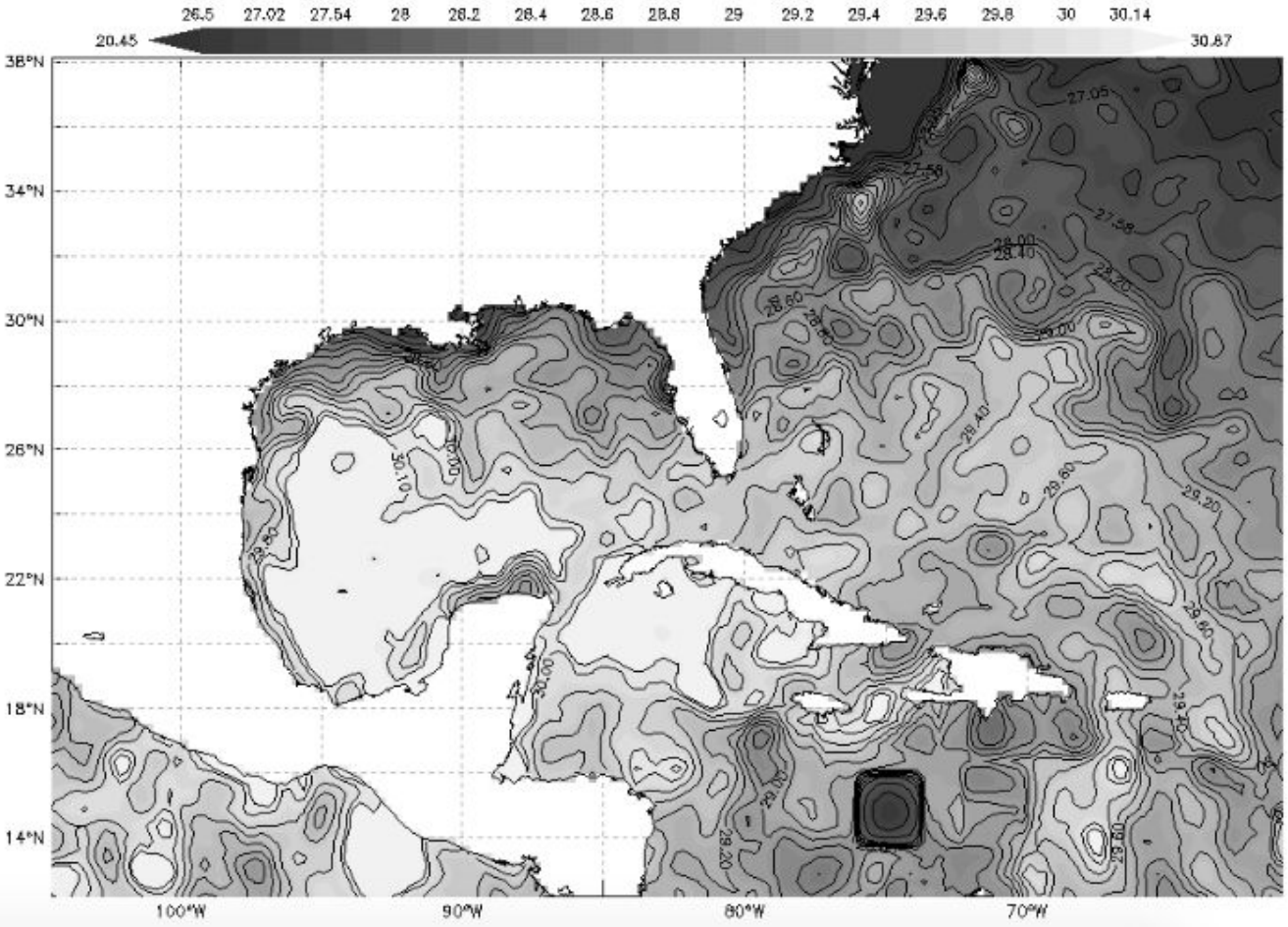
Part B: Going Further Using the same procedure, examine the SST data during and after Hurricane Harvey 2017, Hurricane Irma or any of the historical hurricanes from an area near where you live.	**Data Sources:** My NASA Data: https://mynasadata.larc.nasa.gov/ CYGNSS Mission: https://www.nasa.gov/cygnss

6. Name of Hurricane: Hurricane Joaquin
7. Date of landfall: Oct. 3, 2015
8. How is SST affected by the hurricane that you selected? Temperature a various locations in the Caribbean Sea dropped 3°C
9. What effect do you think these differences in the Hydrosphere might have on other spheres of the Earth system? Fish species, biosphere, that prefer warmer water may be displaced or die.
10. Pose three questions that you might have for further research, in the table below. Identify the types of data that would needed to explore these questions.

New Research Question	New Datasets Needed to Explore this Question
1. Example. How are currents affected by Hurricane Joaquin?	Current velocities for shallow and deep ocean currents
2.	
3.	

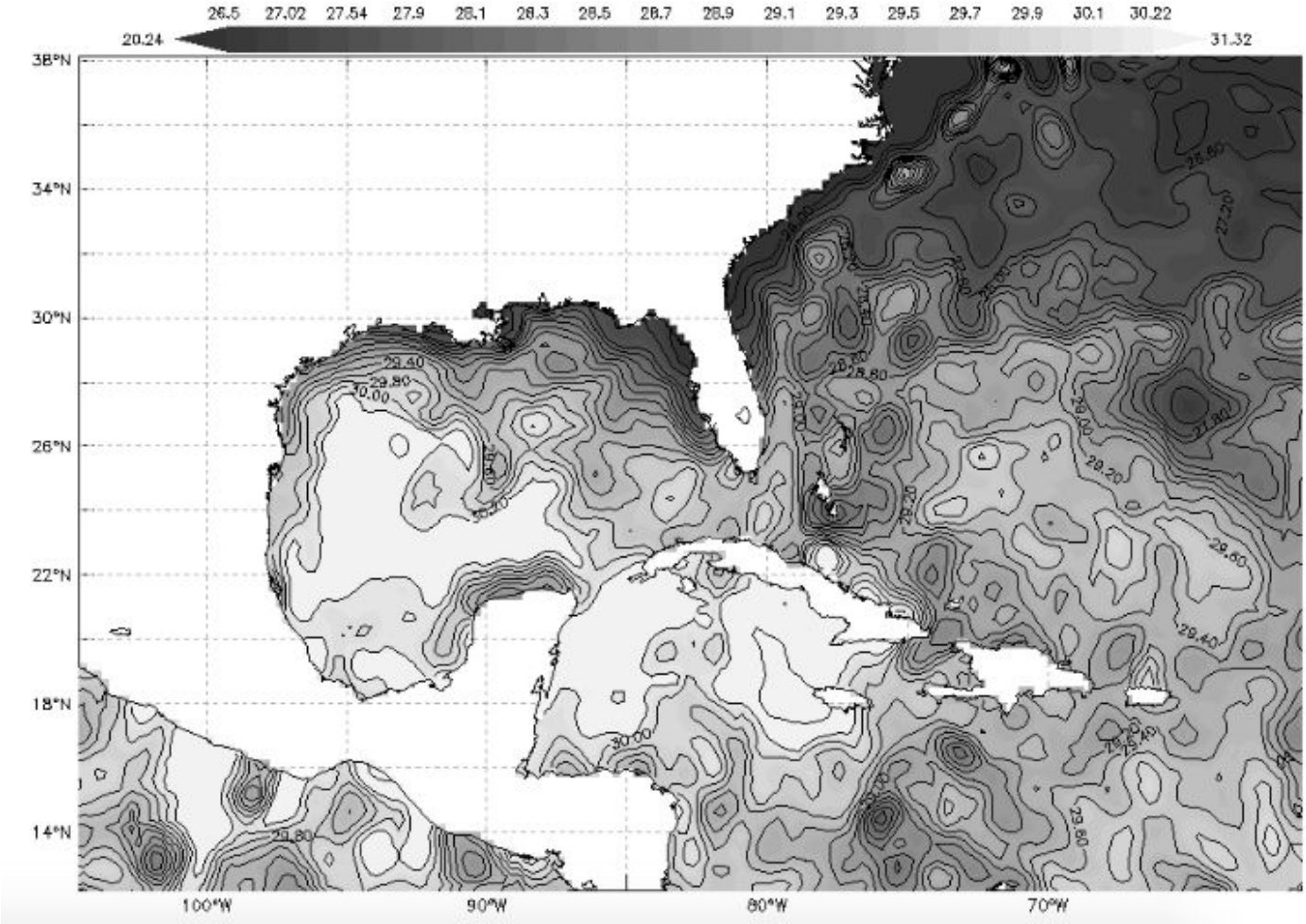
Daily Sea Surface Temperature, Oct. 4, 2016 (Celsius)

Data Visualization



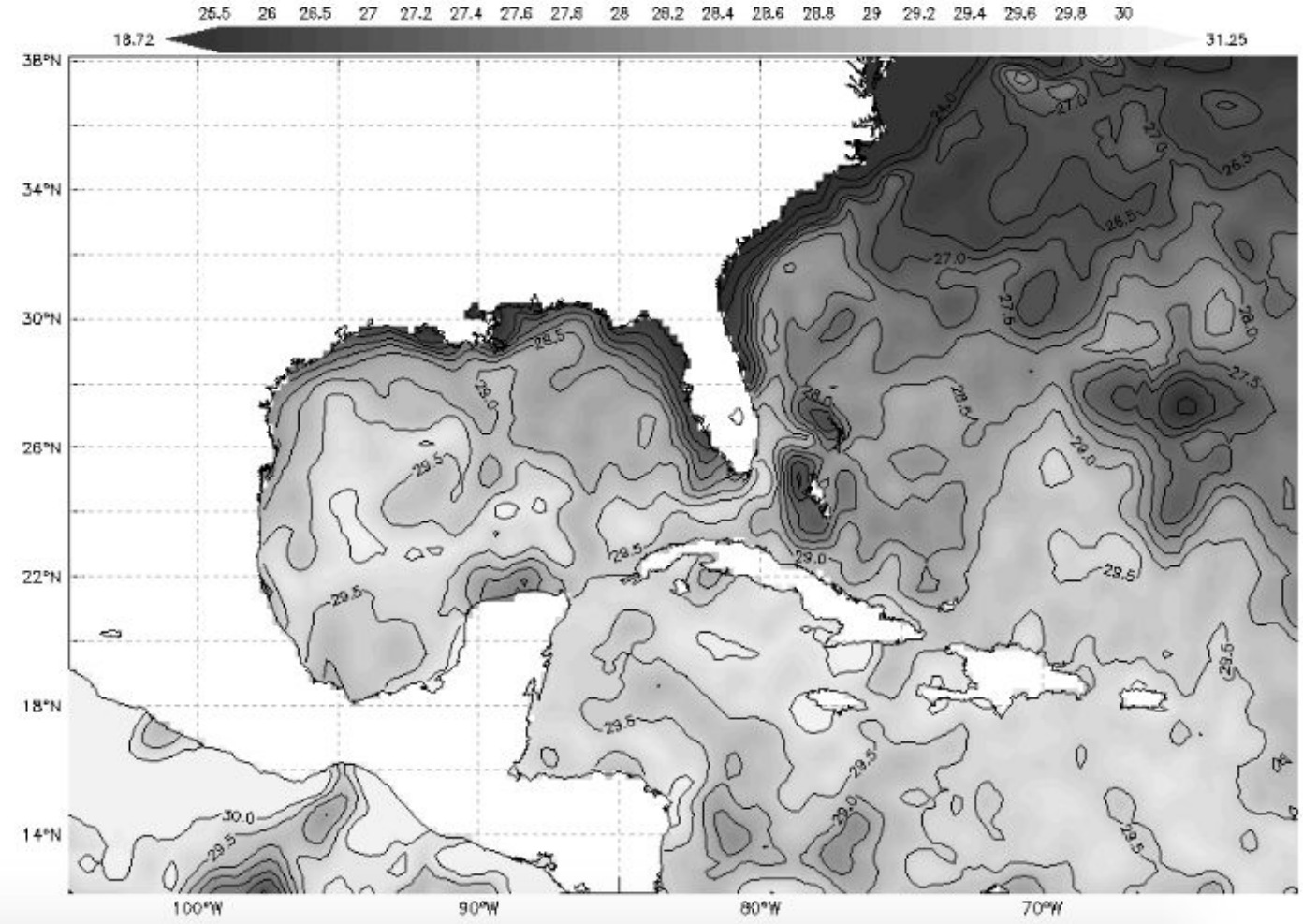
Daily Sea Surface Temperature, Oct. 8, 2016 (Celsius)

Data Visualization



Daily Sea Surface Temperature, Oct. 12, 2016 (Celsius)

Data Visualization



Sea Surface Temperature October 1-16, 2016 (Celsius)

Line Graph of Data